ACCURACY AND LONG-TERM STABILITY OF AMORPHOUS-SILICON MEASUREMENTS

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Presentation Overview

- MEASUREMENT SYSTEM REQUIREMENTS
- CAPABILITIES OF FSA BLOCK V JPL LAPSS SYSTEM
- CONCERNS RELATING TO a-SILICON MEASUREMENTS
- LAPSS SYSTEM IMPROVEMENTS ADDRESSING THE CONCERNS
- OBSERVATIONS OF EXISTING LAPSS SYSTEM
- CONCLUSIONS AND RECOMMENDATIONS

Measurement System Requirements

- DATA ACQUISITION
  - HIGH RESOLUTION AND LINEARITY OF MEASUREMENTS
  - VOLTAGE AND CURRENT MEASUREMENTS TRACEABLE TO NBS
  - LONG-TERM REPEATABILITY OF MEASUREMENTS
  - DEVICE MEASUREMENTS INDEPENDENT OF LEAD RESISTANCE
  - MINIMAL APPLICATION OF BIAS VOLTAGE TO DEVICE
  - SIMULTANEOUS MEASUREMENT OF REF. CELL AND DEVICE
  - ACQUIRE TRUE DEVICE I-V CURVE SHAPE
  - DATA CORRECTION TO DESIRED TEMPERATURE AND INTENSITY

Measurement System Requirements (Cont'd)

- LIGHT SOURCE
  - HIGH STABILITY OF INTENSITY LEVEL
  - LONG-TERM STABILITY OF SPECTRAL IRRADIANCE DISTRIBUTION
  - CLOSE MATCH OF SPECTRAL IRRADIANCE DISTRIBUTION TO THE DESIRED ASTM E 892 AM1.5 GLOBAL SPECTRUM
  - LOW NON-UNIFORMITY OF IRRADIANCE AT TEST PLANE
  - MINIMAL HEATING OF DEVICE
- REFERENCE DEVICE
  - FAST RESPONSE TIME AND STABLE OUTPUT
  - SPECTRAL RESPONSE SIMILAR TO DEVICE
  - CALIBRATION DIRECTLY TRACEABLE TO SUNLIGHT MEASUREMENTS USING ACCEPTABLE ASTM METHOD

FSA Block V JPL LAPSS System Capabilities

- DATA ACQUISITION
  - EXCELLENT LINEARITY AND IMPROVED RESOLUTION
  - FULL SCALE ACCURACY OF ±0.1% TRACEABLE TO NBS
  - IMPROVED LONG-TERM REPEATABILITY, STD. DEV. $\leq$ 1.0%
  - 4-TERMINAL CONNECTIONS TO DEVICE
  - REF. CELL AND DEVICE OUTPUT MEASURED SIMULTANEOUSLY EVERY 20 μ SEC DURING LAMP FLASH
  - DEVICE I-V CURVE SHAPE VERIFIABLE USING FIXED LOAD DURING LAMP FLASH
  - DATA CORRECTED TO DESIRED TEMPERATURE AND INTENSITY USING PREDETERMINED DEVICE TEMPERATURE COEFFICIENTS
  - ADJUSTABLE REVERSE BIAS FOR TRUE I_{SC} MEASUREMENT

FSA Block V JPL LAPSS System Capabilities (Cont'd)

- LIGHT SOURCE
  - LAPSS INTENSITY STABLE TO ±0.5% WITHOUT CORRECTION
  - INSIGNIFICANT CHANGE IN LAPSS SPECTRAL IRRADIANCE DISTRIBUTION THROUGHOUT LAMP LIFETIME
  - NON-UNIFORMITY OF IRRADIANCE IS ≤ ± 1% OVER A 4 x 6 FT TEST PLANE AREA
  - SIGNIFICANTLY SUPERIOR TO A CLASS A SIMULATOR RATING AS DEFINED BY ASTM E 927
  - INSIGNIFICANT HEATING OF TEST DEVICES DUE TO SHORT PERIOD OF ILLUMINATION
  - OPTICALLY FILTERED LAPSS SPECTRAL IRRADIANCE CLOSE TO DESIRED ASTM E 891 AM1.5 DIRECT SPECTRUM
- REFERENCE CELL
  - FAST RESPONSE, STABLE CRYSTALLINE SILICON CELL
  - SPECTRAL RESPONSE SUFFICIENTLY SIMILAR TO ALL CRYSTALLINE SILICONE DEVICES
  - CALIBRATION PERFORMED IN DIRECT NORMAL SUNLIGHT USING PROPOSED ASTM METHOD

Concerns Relating to Amorphous-Silicon Measurements

- POSSIBLE DEVICE DAMAGE FROM EXCESSIVE BIAS APPLIED DURING LAPSS SYSTEM TESTING
- POSSIBLE TEMPORARY SOFTENING OF I-V CURVE KNEE DUE TO LENGTHY APPLICATION OF FORWARD BIAS
- STABILITY AND RESPONSE TIME OF REFERENCE CELL
- SPECTRAL RESPONSE OF REFERENCE CELL
- SPECTRAL IRRADIANCE DISTRIBUTION OF LAPSS

Improvements in the LAPSS System that Addresses the Concerns

- NEGATIVE BIAS LIMITED TO 0.7 VOLTS WITH A PROTECTIVE DIODE
- POSITIVE BIAS OF UP TO 15 VOLTS PRESENT DURING STAND-BY PERIOD ELIMINATED BY CHANGING PROCEDURE
- FAST RESPONSE, STABLE CRYSTALLINE SILICON DEVICE CONTINUED AS REFERENCE CELL
- REFERENCE CELL NOW HAS BUILT-IN IR FILTER TO PROVIDE CLOSE MATCH TO TYPICAL α -SILICON DEVICES
- SPECTRAL IRRADIANCE DISTRIBUTION OF LAPSS OPTICALLY FILTERED FOR CLOSE MATCH TO ASTM E 892 AM1.5 GLOBAL SPECTRUM

Observations of Existing LAPSS System

- PROVIDES RELIABLE AND REPEATABLE MEASUREMENTS OF α-SILICON DEVICE OUTPUT
- INTERNATIONAL COMPARISON OF α-SILICON REFERENCE CELL CALIBRATION SHOWS JPL AND 6 OTHERS WITHIN 2.0% STANDARD DEVIATION OF THE AVERAGE AND JPL MEASUREMENTS NEARLY THE SAME AS SEVERAL PARTICIPANTS
- OBTAINED LIMITED TEMPERATURE COEFFICIENT MEASUREMENTS ON SEVERAL α-SILICON MODULES USING THE LAPSS
- NEW I-R FILTERED REFERENCE CELL HAS LOW SPECTRAL MISMATCH TO A VARIETY OF α-SILICON DEVICES
- OCCASIONAL DIFFICULTY CONTACTING α-SILICON COUPONS WITH PROBES WHEN TESTING WITH LAPSS
- MOST α-SILICON I-V CURVES SHOW A 2 TO 5% SOFTENING OF KNEE AT P_{MAX}

International Comparison of Measurements of Amorphous-Silicon Reference Cell

CELL NO.	MEASUREMENTS (RATIO FROM AVERAGE)						
1	1.022	1.018	1.005	0.992	1.005	0.983	0.975
2	1.039	1.018	1.009	0.996	0.970	0.983	0.983
3	1.027	1.019	1.011	0.994	0.994	0.977	0.977
AVERAGE	1.029	1.018	1.008	0.994	0.990	0.981	0.978

Temperature Coefficients of Amorphous-Silicon Modules (17 to 32°C)

MODULE TYPE	I COEFF ($\mu A/cm^2/^oC$)	E COEFF ($\mu V/CELL/^oC$)	K COEFF ($m\Omega/cm^2/^oC$)	P COEFF (%/°C)
ARCO GENESIS 100	5.5	-2672	-186	-0.15
SOVONICS TANDEM	8.2	-5216	-637	0
SOLAREX	7.2	-4356	-183	-0.14

Spectral Mismatch Parameters of Hypothetical Amorphous-Silicon Devices Versus JPL Pseudo Amorphous-Silicon Reference Cell (JPL Global Filtered LAPSS Versus Proposed New ASTM E 892 Spectrum)

HYPOTHETICAL CELL	WAVELENGTHS FOR 50% RESPONSE		SPECTRAL MISMATCH
	UV	IR	
1	340 nm	TO 680 nm	0.9991
2	360 nm	TO 680 nm	0.9993
3	380 nm	TO 680 nm	0.9998
4	380 nm	TO 700 nm	0.9992
5	380 nm	TO 720 nm	0.9988

Conclusions and Recommendations

- THE VARIANCE AMONG PARTICIPANTS IN INTERNATIONAL CALIBRATION COMPARISON NEEDS TO BE INVESTIGATED
- PRIMARY GLOBAL CALIBRATION OF REFERENCE CELLS IS NEEDED
- SINGLE-POINT LOAD TEST ALWAYS REQUIRED FOR FINDING TRUE P_{MAX}
- MULTIPLE-FLASH WITH SEGMENTED I-V DATA MAY BE DESIRABLE
- MORE RELIABLE PROBE CONTACTING METHOD FOR α-SILICON COUPONS OR USE ONLY DIRECTLY BONDED/ SOLDERED CONNECTIONS
- THE PRESENT JPL LAPSS SYSTEM APPEARS TO BE THE MOST DESIRABLE SYSTEM FOR OBTAINING ACCURATE MEASUREMENTS ON α-SILICON MODULES OF ALL SIZES